Description

Transmission of data in a switchable data network

5 The invention relates to a system and method for transmitting data
in a switchable data network, and to a user in a switchable data
network, in particular switched Ethernet.

Data networks facilitate communication between several users by
10 networking the individual users, which is to say by connecting
them to each other. Communication here refers to the transmission
of data between the users. The data being transmitted is sent in
the form of data telegrams, which is to say said data is assembled
into packets and sent to the relevant recipient in that form over
15 the data network. The term "data packets" is accordingly also
employed. In this document the terms "transmitting data" and
"transmission of data" are used fully synonymously with the above
mentioned transmission of data telegrams or of data packets.
Networking itself is achieved, for example in the case of
20 switchable high-performance data networks, in particular Ethernet,
by switching in each case at least one switching unit between two
users which is connected to both users. Each switching unit can be
connected to more than two users. Users are each connected to at
least one switching unit, but not directly to another user. Users
25 are, for example, computers, stored-program controls (SPS), or
other components which exchange electronic data with other
components and, in particular, process it. Switching units are,
for example, what are termed switches, hubs, bridges, routers, and
the like. In contrast to bus systems, where users can each reach
30 any other data network user directly over the data bus, the
switchable data networks exclusively contain point-to-point
connections, which is to say a user can only reach all other users
in the switchable data network through forwarding by means of one
or more switching units of the data being transmitted. In
35 distributed automation systems, for example in the area of drive
engineering, specific data must arrive at the intended users'
location and be processed by the recipients at specific times.

This is referred to as realtime-critical data or data traffic, because failure of the data to arrive at its destination at the due time will have undesired consequences for the user.

5   DE 100 58 524 A1 describes a system and a method facilitating both realtime-critical and non-realtime-critical communication in a switchable data network consisting of users and switching units, for example of a distributed automation system, by means of a cyclical operating mode. In what is termed a transmission cycle,

10   for all users and switching units of the switchable data network there is in each case at least one sector for transmitting realtime-critical and at least one sector for transmitting non-realtime-critical data, as a result of which the realtime-critical communication is separated from the non-realtime-critical

15   communication. As all users and switching units are always synchronized with a common time base, the respective sectors for transmitting data occur in each case at the same time for all users and switching units, which is to say the realtime-critical communication takes place simultaneously independently of the non-

20   realtime-critical communication and so is not influenced by it. The realtime-critical communication is planned in advance. The injection of the data telegrams at the original sender's side and the forwarding of said telegrams by means of the switching units involved takes place on a time-controlled basis. Through buffering

25   in the respective switching units it is accomplished that any internet-enabled non-realtime-critical communication spontaneously occurring at any time is shifted into that transmission sector of a transmission cycle which is provided for the non-realtime-critical communication and is also only transmitted there.

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The object of the invention is to improve the transmission in a switchable data network of data having a different priority.

Said object is achieved by means of a method for transmitting data

35   in a switchable data network whereby data telegrams are assigned priorities, with said telegrams in each case having a beginning and an end, with data telegrams that were assigned a first

priority being sent during a first phase from first users to second users, with the first phase being characterized by means of a defined receive time of the end of the respective data telegram at the second user.

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Said object is achieved by means of a system for transmitting data in a switchable data network with users which have means for sending, receiving, and/or forwarding data telegrams, with said telegrams in each case having a beginning and an end, and with

10   said telegrams being assigned priorities, with first users being provided during a first phase for sending data telegrams assigned a first priority to second users, with the first phase being characterized by a defined receive time of the end of the respective data telegram at the second user.

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Said object is achieved by means of a user in a switchable data network having means for sending, receiving, and/or forwarding data telegrams, with said telegrams in each case having a beginning and an end, and with said telegrams being assigned

20   priorities, with the user being embodied as the first or second user, with the first user being provided during a first phase for sending data telegrams assigned a first priority to second users, with the first phase being characterized by a defined receive time of the end of the respective data telegram at the second user.

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The invention is based on the knowledge that the transmitting of data telegrams assigned different priorities within a switchable data network results in unsatisfactory results if the data telegrams are not suitably transmitted in a sequence depending on

30   the respectively assigned priority. Differences in the length of those data telegrams assigned a highest priority in particular result in partially considerable delays in the transmission of data telegrams of next-lower priority. According to the invention, a first phase is defined during which those data telegrams

35   assigned a first priority are transmitted between the users, said first phase being characterized by a defined receive time of the end of the respective data telegram at the receiving user. In

contrast to the prior art, the first phase is therefore not characterized by a rigidly fixed start time the consequence of which is that the receive times of the telegram ends are distributed over time in an uncoordinated manner depending on the

5 respective telegram length. According to the invention, the first phase is instead characterized by a defined receive time of the end of the respective data telegram at the receiving user, where the term "defined receive time" is to be understood as a pre-specified and planned receive time which is known in the system

10 and which has been coordinated among the users. The defined receive time of the end of the respective data telegram thus results in optimized planning of the transmission in a switchable data network of data having different priority, whereby the end of the first phase is defined on a coordinated basis between the

15 users.

According to an advantageous embodiment of the invention, only data telegrams assigned a second priority are sent in a second phase after the end of the first phase. The advantage of this is that, after highest-priority data telegrams sent in the first

20 phase, data telegrams assigned the next-lower priority can preferably be sent in the second phase. The transmission of lower-priority data telegrams which could otherwise impede the transmission of the higher-priority data telegrams is thus avoided during this second phase. On completion of the first phase, a

25 second phase, namely the waiting time, is thus started during which lower-priority data telegrams can continue being blocked, but higher-priority data telegrams are let through. Said waiting time is advantageously selected to be of the same length as the overall time for forwarding a data telegram from the user at the

30 beginning of a transmission link to the user at the end of a transmission link within the data network. This embodiment of the invention thus enables higher-priority data telegrams to be channeled through a switchable data network without any special planning requirements and with modest expenditure.

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To facilitate the transmission and forwarding of lower-priority data telegrams within the data network, according to a further

advantageous embodiment of the invention, data telegrams assigned
any priority are sent in a third phase after the end of the second
phase. A third phase for transmitting data telegrams of any
priority is thus made available after data telegrams having a high
5   and highest priority have been sent in the second or, as the case
may be, first phase.

According to a further advantageous embodiment the invention can
perform cyclical communication tasks within a switchable data
10   network if the first phase is cyclically repeated. A cycle
expediently ends or, as the case may be, begins at the time of the
defined end of the first phase, which is to say at the defined
receive time of the end of the respective data telegram at the
receiving user.
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To make the transmission of data, in particular realtime data,
within a data network as calculable as possible, according to a
further embodiment of the invention, data telegrams with realtime
data are assigned the first priority.
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The invention is described and explained in more detail below with
reference to the exemplary embodiments shown in the figures, in
which:

25   FIG 1   is a schematic of a switchable data network,

     FIG 2   is a schematic of the routing of soft realtime data
               through an isochronous realtime network,

30   FIG 3   is a schematic of an instance of communication between
               users in a conventional data network, and

     FIG 4   is a schematic of an instance of communication between
               users in a system according to an exemplary embodiment
35   of the invention.

FIG 1 is a schematic of a switchable data network 15. The data
network has users 1 - 14 among all of which a communication
coupling exists over communication connections 20 - 32. Users 1 -
14 in data network 15 are switching elements (users 1 - 5), what

5   are termed switches, for instance, an intra-/internet (user 6),
and other users 7 - 14, for instance components of an automation
system, which can communicate with each·other and with other
components over data network 15. Data network 15 is a switched
network, which is to say that in contrast to what is termed a

10   shared-medium network the communication participants in network 15
do not communicate with each other over a shared communication
medium but over point-to-point communication connections 20 - 32.
In the exemplary embodiment, communication in data network 15 is
coordinated by users 1 - 5 embodied as switching elements such as

15   switches, for instance. A switch customarily has means for
sending, receiving, and/or forwarding data telegrams, in
particular input ports with input buffers, a switch matrix, output
ports with output buffers, an address/port assignment table,
switch control software, and switch management software. There is

20   a resulting difference in the behavior of the switch depending on
the principle and implementation of these elements. A switch
generally serves as a very fast packet switching system. A packet
or a telegram arriving at an input port is switched through on the
basis of its destination address to the correct output port in

25   unmodified form. The switch analyzes the packet on its arrival,
decides on the basis of a stored address table to which output
port the packet belongs, and dispatches it over this output port
as soon as possible. Switches are customarily optimized for speed.
As many elements as possible are for this reason implemented in

30   the form of fast hardware (in contrast to routers, which are
predominantly software implementations). In the exemplary
embodiment, user 1 forwards data packets coming from users 7 - 9
over communication connection 20 to user 2. Vice versa, data
packets coming from user 2 are forwarded by user 1 to the single

35   user or the respectively addressed users 7 - 9. Users 1 - 5
forward the data telegrams sequentially, which is to say one after
the other. Switched data network 15 can be connected via suitable

switching elements to shared-medium networks and/or an intra-
/internet 6.

Realtime communication is subject in automation systems to varying
5   requirements. As an instance of this, updating times, for example,
or, as the case may be, response times may at the most be in the
range of a few milliseconds. The term 'updating time' is to be
understood here as the length of time required to form a variable
in an application of a user 1 - 14, to send said variable to
10   another user 1 - 14 over a communication connection 20 - 32, and
to make said variable available there in the application. The
following factors are customarily responsible for the updating
rate between two users 1 - 14. The updating rate is inversely
proportional to the throughput time of data or, as the case may
15   be, telegrams between users 1 - 14. The throughput time comprises
the time taken to make the data available in sending user 1 - 14,
the time taken to process the respective communication tag in
sending user 1 - 14, the time taken for transmission over the
communication connection 20 - 32, the time taken to process the
20   communication tag in receiving user 1 - 14, and the time taken to
process the receiving [sic] data in user 1 - 14.

FIG 2 is a schematic of the routing of what is termed soft
realtime data (SRT data) through an isochrones realtime network
25   (IRT network). An IRT system is described, for example, in the
above-mentioned DE 100 58 524 A1. IRT communication is here
characterized by the fact that for all users and switching units
of the switchable data network in each case at least one sector
for transmitting realtime-critical and at least one sector for
30   transmitting non-realtime-critical data are provided in a
transmission cycle. The realtime-critical data provided for
transmitting in this first sector is referred to below as IRT
data. This IRT data is subject to particularly stringent realtime
requirements, which is to say that a deterministic characteristic
35   is expected of this data. The term 'SRT data' is to be understood
as realtime data which is subject to less stringent realtime
requirements than the IRT data. SRT data can be, for example,

cyclical realtime data. The two data networks 40, 44 shown in FIG 2 serve SRT data as a communication network. The third data network shown is, by contrast, an IRT data network 45 designed according to the rules and requirements of isochronous realtime

5 communication. The SRT networks 40 and 44 are connected to IRT network 45 over communication connections 41 or, as the case may be, 43. The purpose of the dashed line in FIG 2 is to represent the routing of an SRT data telegram 42 through IRT data network 45. An SRT data telegram 42 is customarily routed through said

10 network according to the rules of IRT data network 45.

FIG 3 is a schematic of an instance of communication between users in a conventional data network. It shows four users 1 - 4 connected linearly over point-to-point communication connections.

15 The four users 1 - 4 could, for example, correspond to users 1 - 4 embodied as switching elements in data network 15 shown in FIG 1, and so are identified here with the same reference numbers. Also shown schematically in a place-time diagram are data telegrams exchanged between users 1 - 4. The data telegrams, referred to

20 below for short as telegrams 55 to 65, are transmitted from user 1 over communication connection 20 to user 2, from user 2 over communication connection 21 to user 3 or, as the case may be, from user 3 over communication connection 22 to user 4. The horizontal axis in the direction of advancing time of the place-time diagram

25 is characterized with time arrow 50. The dashed vertical lines 51 and 52 accordingly in each case characterize a discrete time in the place-time diagram. The schematic in the place-time diagram shows various types of telegram characterized by different hatching. In the case of the communication shown here within an

30 IRT network, IRT telegrams 60 - 62 and 63 - 65 start in each case at the same time 51 or, as the case may be, 52. SRT telegrams 55 - 57 are also routed through the IRT data network like NRT telegrams 58, 59 (NRT telegrams: Non Realtime Telegrams, which is to say telegrams whose transmission is not subject to any realtime

35 requirements).

Various functions within internet-Ethernet communication make it necessary for transmission within a network to be as calculable as possible. The possible collision-waiting situations on the lines (in the case of shared-medium networks or in the switches in the

5 case of switched networks) result in a not-deterministic characteristic. Although the introduction of priorities for realtime traffic in a network with a large number of switches with spontaneous and cyclical but uncoordinated communication produces an averagely satisfactory transmission time, situations

10 nonetheless arise in which high-priority messages are significantly delayed. The previously known methods require what is termed 'scheduling'. This avoids waiting situations. In the case of shared-medium networks, each user must adhere to said scheduling. This, however, makes it impossible to connect any

15 users no matter which with already existing hardware or, as the case may be, software. In the case of switched networks it suffices when all participating switches enforce said scheduling. This makes it possible to connect any end-users no matter which. A method known for this is the above-mentioned IRT communication.

20 Although said method can be employed for any topologies, it requires filing of the planning data of the deterministic communication traffic not only at the participating end nodes but in all participating routing switches. Moreover, although a simple node could be attached to an IRT system, this is not possible for

25 a group of simple devices over a conventional switch. Moreover, elaborate and time-critical special software has to be developed even in the case of simple nodes. If further realtime data, in particular cyclical realtime data, is injected into an IRT network on an uncoordinated basis, blocking of normal message traffic will

30 cause delays at the end of an IRT cycle. After the IRT phase, which can be of differing length for different users, another lower-priority message can be sent in the case of one user while an IRT phase is still in progress in the case of another.

35 This frequently occurring problem of communication within an IRT data network, in particular in the case of the routing of SRT telegrams through the IRT data network shown in FIG 2, will be

explained below with the aid of FIG 3. In order to meet the realtime requirements, particularly when IRT data packets are being transmitted, within a switched data network, the data telegrams are customarily transmitted on a planned basis in terms

5 of time flow, which is to say with the application of what is termed 'scheduling'. A provision of scheduling in an IRT data network is that all users 1 – 4 in the data network transmit the highest-priority IRT data telegrams 60 – 62 or, as the case may be, 63 – 65 at pre-defined times 51 and 52. The discrete times 51

10 and 52 are separated by a defined time interval 67. This thus results in cyclically repeating transmission intervals beginning in each case with an IRT phase for transmitting IRT data telegrams, which is immediately followed by a second phase provided for transmitting less time-critical data telegrams.

15 Scheduling prevents SRT telegrams 55 and NRT telegrams 58, 59 from being transmitted between users 1 – 4 during the IRT phase at the start of a transmission cycle. In the example in FIG 3, both SRT telegram 55 and NRT telegram 58 must therefore be buffered at the time 51 in user 2 or, as the case may be, 3, so that the highest-

20 priority IRT data telegrams 61 or, as the case may be, 62 can be transmitted. When IRT telegrams 60 – 62 and 63 – 65 have been transmitted, the remaining time within the transmission cycle can be used for transmitting SRT telegrams 55 – 57 or, as the case may be, NRT telegrams 58, 59. In this case, therefore, SRT telegram 56

25 is forwarded from user 2 to user 3 after NRT telegram 61, and NRT telegram 59 is correspondingly forwarded from user 3 to user 4 after IRT telegram 62. The routing times through users 1 – 4 and the transmission times over communication connections 20 – 22 are shown in FIG 3 by the time difference 66 between the send and

30 receive time. To obtain as good a realtime characteristic as possible for the communication network, it would be desirable also for the high-priority SRT telegrams 55 – 57, as well as the highest-priority IRT telegrams 60 – 65, to be routed through the data network with minimum delay. It must be said, however, that

35 the scheduling shown in the example in FIG 3 cannot prevent transmission of SRT telegram 56 in the same transmission cycle from being blocked by transmission of NRT data telegram 59. User 3

can only forward SRT telegram 57 to user 4 in the next
transmission cycle, with higher-priority IRT telegram 65 being
transmitted first. The consequent undesired transmission sequence
in the IRT data network is due to the common start times of IRT
5   telegrams 60 - 62 customarily provided by the scheduling and the
different length of said IRT telegrams 60 - 62.

FIG 4 is a schematic of an instance of communication between users
in a system according to an exemplary embodiment of the invention.
10   FIG 4 shows, analogously to FIG 3, a switchable data network with
users 1 - 4 connected through communication connections 20 - 22,
and a place-time diagram to illustrate the transmission of data
telegrams 70 - 77. In contrast to the embodiment of the data
network in FIG 3, communication in the data network according to
15   FIG 4 does not take place in accordance with the previously
described customary rules of an IRT data network. Communication
between users 1 - 4 also takes place in the case of the exemplary
embodiment of the invention shown here in accordance with a
planned time flow, which is to say with the application of what is
20   termed 'scheduling'. However, appropriately optimized scheduling
is employed to avoid the problems depicted with the aid of the
example in FIG 3 associated with the routing of SRT telegrams
through an IRT data network. As the lengths of telegrams 70 - 77
being transmitted are known in the system and hence in the
25   individual users 1 - 4, the transmission of an IRT telegram 75 -
77 can be planned and implemented in such a way that the time of
the end of transmission of an IRT telegram 75 - 77 in the
respectively receiving user 2 - 4 and hence also the time of the
end of the first phase is defined. A time defined in this way of
30   the end of the first phase could, for example, be the same time
for all users, which is to say the transmission of all IRT
telegrams 75 - 77 in the data network ends at the same previously
defined time (not shown in FIG 4). If the respective routing times
66 are additionally taken into consideration, it is possible to
35   achieve an end of transmission of the respective IRT telegrams 75
- 77 which appears flush in the place-time diagram. In this case
the defined times of the end of transmission of an IRT telegram

75 - 77 in the respectively receiving user 2 - 4 and hence also the times of the end of the first phase in the receiving user are therefore in each case displaced by the routing times 66 in relation to the respective time at the sending user. A waiting
5 time 80 during which the forwarding of NRT telegrams 74 is prevented is provided immediately following the thus optimized IRT phase. SRT telegrams 71, 72 are, however, forwarded in this phase. Users 1 - 4 forward receiving [sic] SRT telegrams 71, 72 as quickly as possible using the cut-through method. Thanks to the
10 cut-through method, the delay experienced by the telegrams when being routed is minimized. This is achieved by simultaneous evaluation of an arriving telegram 71, 72 by user 1 - 4. Despite not having been completely received, the telegram can already be sent again on an appropriate port of the respective user 1 - 4
15 when the destination address has been properly recognized. The fastest possible routing of high-priority SRT telegrams 70 - 72 through an IRT system is achieved thanks to the end-isochronous transmission of IRT telegrams 75 - 77, in particular in combination with the definition of a waiting time 80 before NRT
20 telegrams 73, 74 are routed.

To summarize, the invention thus relates to a method and system for transmitting data in a switchable data network and to a user 1 - 4 in a switchable data network. To improve the transmission of
25 data having different priority in the switchable data network, it is proposed assigning data telegrams 70 - 77 priorities, with said telegrams 70 - 77 in each case having a beginning and an end, with data telegrams 75 - 77 that were assigned a first priority being sent during a first phase from first users 1 - 3 to second users 2
30 - 4, with the first phase being characterized by means of a defined receive time of the end of the respective data telegram 75 - 77 at the second user 2 - 4.